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PROPER RETROFIT FURNACE SIZING

Introduction

Residential furnaces work best when they are properly sized. A furnace that is too large will cycle on and off quickly, with some inefficiencies of operation. This can lead to rooms furthest from the furnace remaining cool or to furnace chimneys deteriorating due to excessive condensation. As well, some of the furnace controls or parts may break down sooner than expected due to a high cycling frequency. Furnaces that are undersized may not keep the house at a comfortable temperature in the coldest parts of the winter. It will take much longer for an undersized furnace to bring a house back up to temperature after the thermostat has been turned down for a period (e.g. night setback, vacation). There is a Canadian Standards Association (CSA) standard on how to properly size furnaces. It is called "Determining the Required Capacity of Residential Space Heating and Cooling Appliances", CAN/CSA F280-M90 (R1998). It provides a procedure to calculate house heat losses for the "design temperature" for the location of the house. The standard lists the design temperature for most Canadian communities. The design temperature is equivalent to one of the coldest temperatures a community is expected to experience in any given winter. The standard specifies that the heating system shall be no more than 40 per cent larger than the heat required for the house at that design temperature. The 40 per cent allowance provides some margin for error in the calculation and also permits some oversizing to bring a house back up to temperature. Basically, this sizing calculation will recommend a furnace that runs at least 35-40 minutes every hour on the coldest day of the year.

There are several ways that contractors can estimate house heat loss. The most accurate way is to time the furnace run time on the coldest day of the year and, using the furnace size and efficiency, calculate house heat loss. However, few people have the foresight or interest to do this. A second way is for the contractor to perform a calculation based on CAN/CSA F280 on the house. This is possible but requires finding a contractor with the appropriate skills. A good estimate will take several hours, with a corresponding cost. Most heating contractors do not properly estimate house heating loads.
For replacement furnaces, contractors simply specify a furnace about the size of the existing furnace, or perhaps marginally smaller due to energy saving measures that have been undertaken. Homeowners rarely recognize furnace oversizing and do not complain. They will complain, however, if a furnace is undersized. These conditions result in most gas or oil furnaces in Canada being grossly oversized, up to 250 per cent bigger than they need to be.

CMHC hired the Saskatchewan Research Council (SRC) to develop a furnace sizing protocol that uses the actual meter readings from gas billing to size replacement gas furnaces. Oil furnaces do not have meters. It may be possible to adapt this sizing technique to oil tank filling bills, but this extension of the research was not part of the SRC contract.

The second part of the contract was to quantify the savings due to proper furnace sizing when replacing heating systems.

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Research Program

SRC located 26 houses with cooperative owners and good utility records. The goal was to find a relationship between the gas consumed and the heating degree days (HDD). A heating degree day is essentially the number of degrees of heating required over the course of 24 hours and is compared to a base of 18 °C. For example, if the average daily outside temperature is 10 °C, then the number of heating degree days for that day is 18 °C - 10 °C = 8 HDD. The HDD are available from Environment Canada data. In the SRC study, once the relationship of the HDD and gas consumption was established, then the gas consumption was calculated for a Saskatoon design temperature of -35 °C (which works out to 53 HDD on that cold day). The natural gas usage of other gas-fired appliances in the houses were estimated from SaskEnergy data and subtracted from the total for the period in question, so that the gas requirement for heating could be isolated.

Three sources of data were tested:

1. Ten householders had specific gas meter records for the start and end of January (this was called the "January" calculation procedure in the report).

2. All 26 householders had long term utility billing data from which various consumption periods could be extracted ("historical" procedure).

3. All 26 households were also tested using a single season, mid-winter utility bill. The local gas utility records meter readings on a three month schedule. The difference between the March reading and the December reading was tested on all 26 houses ("utility" procedure).

For calculations of savings attributable to proper sizing, six houses were chosen at random and modelled using the HOT2000 residential modelling software package (version 8.72).

Here is an example calculation, using the three month meter (utility) reading for an example house, where a conventional furnace (efficiency of 72%) is being replaced by a mid-efficiency furnace (efficiency of 80%).

Total gas consumption from actual meter readings December to March = 1 320 cubic metres (m^3)
Estimated consumption for other appliances (from SaskEnergy) = 306 m^3
Therefore, gas consumption during the period for heating = 1,320 - 306 = 1,014 m^3
Heating degree days for that period (from Environment Canada data) = 2,840 HDD
Heating consumption vs degree days = 1,014 m^3/ 2,840 HDD = 0.3570 m^3/HDD
Heating consumption at 53 HDD/day = (53 HDD/day)(0.3570 m^3/HDD) = 18.9 m^3/day
Where gas has an energy content of 37.5 megajoules per cubic metre (MJ/m^3), and the furnace has a steady state efficiency of 72 per cent, then:
Heat loss at 53 HDD/day = (18.9 m^3/day)(37.5 MJ/m^3)(0.72) = 510 MJ/day or 21.3 MJ/h.
As 3.6 MJ/h = 1 kW, then 21.3 MJ/h = 5.9 kW
This heat loss would require a furnace that produces an output of 5.9 kilowatts (kW) or 20,100 British thermal units per hour (Btu/h).

If we allow the CAN/CSA F280 allowable oversizing of 40 per cent, then the proper furnace output sizing would be (1.4)(5.9 kW) = 8.26 kW (or 28,100 Btu/h)

The new furnace being installed in this house has a rated input of 35.2 kW (120,000 Btu/h). At the rated efficiency of 80 per cent, this results in a heat output to the house of 28.2 kW (96,000 Btu/h). Therefore, the furnace size is 28.2 / 8.26 (96,000/28,100) = 342 per cent of the heat required or 242 per cent more than is required.

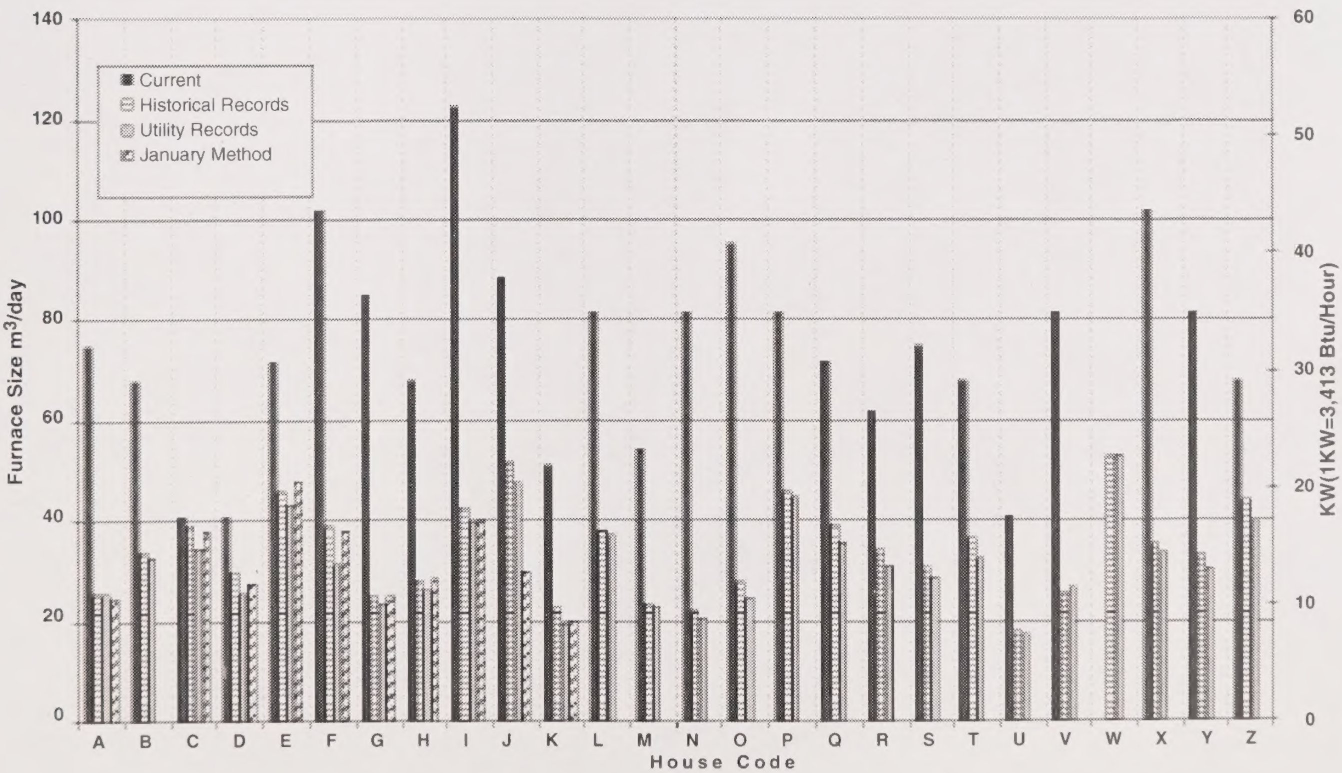
Findings

All three sizing methods provided results consistent with each other. The historical data provided the most extensive and likely most precise estimation technique. The calculated heat losses using the more variable January and utility records were within ± 10 per cent of the historical records, with only a couple of explainable exceptions.

Replacement furnace sizes (for 80% efficient furnaces) were calculated by the three methods and compared to the existing furnaces in the houses (which were predominantly conventional efficiency furnaces). It is clear that the majority of furnaces were grossly oversized. See the figure.

The other part of the research, calculating the energy savings due to proper replacement furnace sizing, proved less successful. There is data showing that proper sizing of conventional furnaces (natural draft) reduces gas consumption. However, in Canada, one cannot purchase new conventional furnaces any longer due to energy efficiency regulations. The only gas furnaces now sold in Canada are either mid-efficiency (typically 80% steady state efficient) or high efficiency furnaces (90-95% efficient). There is no good data showing whether these higher efficiency furnaces do save energy as a result of being properly sized. The HOT2000 simulations therefore showed no appreciable savings. A properly sized furnace will run longer and cycle less frequently, which may lead to longer component life. Bigger furnaces tend to have bigger circulation fans, which will require higher amounts of electricity, so there may be some savings available due to reduced electrical usage. However, the real advantages of proper sizing await the results of testing on the cyclic efficiencies of mid and high-efficiency furnaces.

Furnace Sizes



Implications for the Housing Industry

The three techniques for determining house heat loss were remarkably successful. This means that most households or contractors now have alternative ways to calculate house heat loss in existing houses and to properly size heating equipment.

However, because we currently lack proof that proper saving of higher efficiency furnaces lends to energy savings, the utility of this research is limited.

Project Manager: Don Fugler

Research Consultant: Saskatchewan Research Council

Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

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or contact:

Canada Mortgage and Housing Corporation
700 Montréal Road
Ottawa, Ontario
K1A 0P7

Phone: 1 800 668-2642
Fax: 1 800 245-9274

OUR WEB SITE ADDRESS: www.cmhc.ca

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